International Journal of Agricultural Science and Research (IJASR)
ISSN (P): 2250-0057; ISSN (E): 2321-0087
Vol. 9, Issue 3, Jun 2019, 277-282

SPATIAL ESTIMATION OF NET RADIATION BY SURFACE ENERGY BALANCE ALGORITHM FOR LAND IN LALGUDI BLOCK

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ABSTRACT

The objective of this paper is to spatially estimate the net radiation by surface energy balance algorithm for land (SEBAL)model. The study was conducted in Lalgudi block of Trichy district, Tamil Nadu, India. Landsat 8 satellite images for four selected scenes (December 2014 & January 2015 and December 2017 & January 2018) were used to estimate the net radiation from the SEBAL model. The maximum net radiation was observed in water bodies that were around 650 W m^{-2}. The net radiation was lesser (450 W m^{-2}) from sand bed compared to all the other land uses. The net radiation from Paddy, sugarcane, Banana, Forest area, Coconut, and Prosopis was in the rangeof 560 to 600 W m^{-2}. The net radiation from barren land was in the range of 530 to 560 W m^{-2}. These results present SEBAL as a vital tool to be used in hydrological and environmental studies.

***KEYWORDS**: Net Radiation; SEBAL & Landsat 8*

Received: Apr 12, 2019; **Accepted**: May 02, 2019; **Published**: May 21, 2019; **Paper Id.**: IJASRJUN201940

Original Article

INTRODUCTION

Net radiation (R_n) is the most important parameter for computing the evapotranspiration and is a driving force for other physical and biological processes (Samani et al., 2007). Small changes in solar radiation may have a considerable effect on the calculated value of reference evapotranspiration (Llasat and Snyder, 1998). It is also used for climate monitoring, weather forecast and agricultural meteorology (Bisht et al., 2005).

Net radiation is the difference between incoming and outgoing radiation of both short and long wavelengths. It is the balance between the energy absorbed, reflected and emitted by the earth's surface or the difference between the incoming net shortwave (R_{ns}) and the net outgoing longwave (R_{nl}) radiation (Allen et al., 1998). The total daily value for R_n is almost always positive over a period of 24 hours, except in extreme conditions at high latitudes. These data depend mainly on the latitude and geographical situation of the concerned area.

Conventional methods of measuring surface energy balance are point measurements and represent only a small area. Remote sensing offers a potential means of measuring outgoing fluxes over large areas at the spatial resolution of the sensor. It is an innovative tool to observe land surface processes on a large spatial scale and low cost-effective (Cai and Sharma, 2010).

SEBAL is one of the best remote sensing models to estimate spatial energy fluxes because it calculates the fluxes independently from land cover and can handle thermal infrared images at resolutions between a few meters and several kilometers. In the SEBAL model, the net radiation in estimated by balancing the energy absorbed, reflected and emitted by the earth's surface (Bastiaanssen et al., 1998). Costa dos Santos et al. (2011) estimated the spatial distribution of net radiation in two contrasting vegetation covers (forest and pasture) through the SEBAL algorithm in the state of Rondônia in northwestern Brazil, using four Landsat TM images, as well as, digital elevation model data. Lisboaet al. (2016) assessed the net radiation in different land uses at Rio de Janeiro using the SEBAL algorithm. The study also reported different net radiation values from a waterbody, flooded area, vegetation, agriculture, urban area, and exposed soil.

The aim of this paper is to estimate the net radiation by using surface energy balance algorithm for the land model in Lalgudi block of Trichy district, Tamil Nadu, India. The Lalgudi block has dense dry vegetation and barren lands in the northern part. The southern part is bounded by River Coleroon. The Lalgudi Town is located at the central part of the block. Around 80% of the block has cultivated lands in which paddy, banana, and sugarcane are the major crops.

MATERIALS AND METHODS

Data Used

To maintain homogeneity in the dataset, two pairs of Landsat 8 satellite images of December 05, 2014 & January 22, 2015, and December 29, 2017, & January 30, 2018, were acquired from USGS website. The period of images taken was based on paddy cultivation season. Table 1 presents image acquisition date, solar elevation angle and zenith angle for the Landsat 8 data products used.

Table 1: Meta Data of Landsat 8 Image used

S. No.	Acquisition Date (yyyy-mm-dd)	Solar Elevation Angle (Degrees)	Solar Azimuth Angle (Degrees)	Cloud Cover in Image (%)	Cloud Cover in Study Area (%)
1	2014-12-05	49.38	146.60	2.46	0.77
2	2015-01-22	48.22	138.31	0.01	0.00
3	2017-12-29	47.08	144.18	23.15	0.40
4	2018-01-30	49.39	135.62	0.17	0.00

Estimation of Net Radiation using SEBAL Model

The surface radiation balance equation was used to estimate the net surface radiation flux (R_n). The net radiation flux at the surface represents the actual radiant energy available at the surface. It was calculated as the difference between all incoming and outgoing radiation fluxes. The equation is as follow as:

$$R_n = R_{S\downarrow} - \alpha R_{S\downarrow} + R_{L\downarrow} - R_{L\uparrow} - (1-\varepsilon_s) R_{L\downarrow} \tag{1}$$

Where $R_{S\downarrow}$ is the incoming shortwave radiation (Wm^{-2}); α is the surface albedo; $R_{L\downarrow}$ is the incoming long wave radiation ($W\ m^{-2}$); $R_{L\uparrow}$ is the outgoing long wave radiation and ε_o is the surface thermal emissivity. The illustration of surface radiation balance components is depicted in fig 1. Each component in equation 1 was estimated separately.

Estimation of Surface Albedo (α)

Surface albedo (α) is defined as the amount of reflected back by the surface. It is calculated as the ratio of the difference between planetary albedo (α_{toa}) and atmospheric albedo (α_{atm}) of each pixel to the square of atmospheric

transmittance (τ). The equation is given by (Bastiaanssen et al., 1998):

$$\alpha = \frac{(\alpha_{toa} - \alpha_{atm})}{\tau^2} \tag{2}$$

Incoming Shortwave Radiation ($R_{S\downarrow}$)

Incoming shortwave radiation is the direct and diffuse solar radiation flux that actually reaches the earth's surface (W m^{-2}). It was calculated using:

$$R_{S\downarrow} = G_{sc} \times \cos z \times d_r \times \tau_{sw} \tag{3}$$

where; G_{sc} is the solar constant (1367 W m^{-2}), cos θ is the cosine of the solar incidence angle, d_r is the inverse squared relative earth-sun distance, and τ_{sw} is the atmospheric transmissivity. The values of $R_{S\downarrow}$ can range from 200 – 1000 W m^{-2} depending on the time and location of the image.

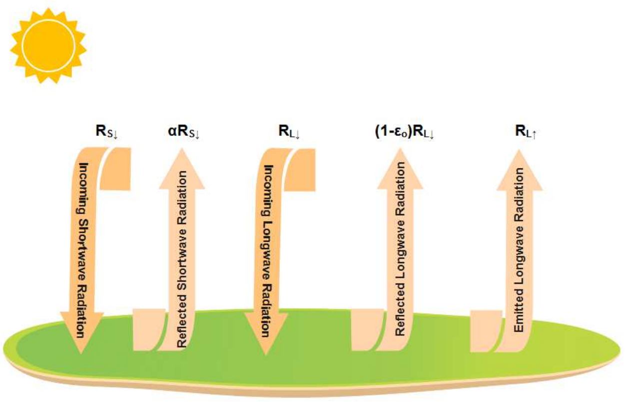


Figure 1: Surface Radiation Balance Components

Outgoing Long wave Radiation ($R_{L\uparrow}$)

The outgoing longwave radiation is the thermal radiation flux emitted from the earth's surface to the atmosphere (W m^{-2}). SEBAL estimates the outgoing longwave radiation as a function of vegetative indexes, surface emissivity, and surface temperature. The outgoing longwave radiation ($R_{L\uparrow}$) is computed using the Stefan-Boltzmann equation as follow as:

$$R_{L\uparrow} = \varepsilon_s \times \sigma \times T_s^4 \tag{4}$$

where; ε_s is the surface emissivity (dimensionless), σ is the Stefan-Boltzmann constant (5.67 × 10^{-8}W m^{-2} K^{-4}), and T_s is the surface temperature (K). Values for $R_{L\uparrow}$ can range from 200 – 700 W m^{-2} depending on the location and time of the image.

Incoming Long wave Radiation ($R_{L\downarrow}$)

The incoming longwave radiation is the downward thermal radiation flux from the atmosphere (W m^{-2}). It was also computed by using the Stefan-Boltzmann equation:

$$R_{L\downarrow} = \varepsilon_a \times \sigma \times T_a^4 \tag{5}$$

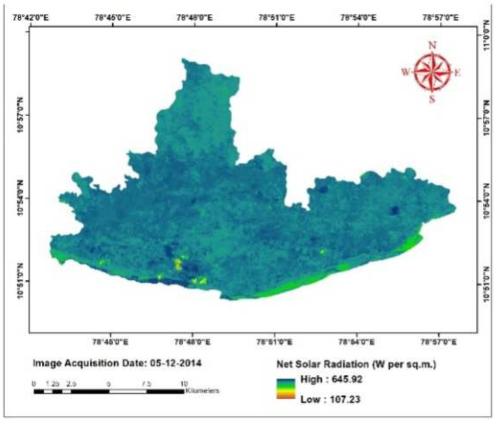
where; ε_a is the atmospheric emissivity (dimensionless), σ is the Stefan-Boltzmann constant (5.67×10^{-8}W m^{-2} K^{-4}), and T_a is the near-surface air temperature (K). Values for $R_{L\downarrow}$ can range from 200 – 500 W m^{-2}, depending on the location and time of the image.

Net Surface Radiation Balance (R_n)

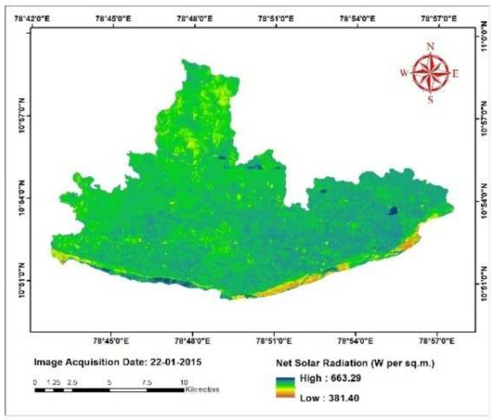
From surface albedo (α), outgoing longwave radiation ($R_{L\uparrow}$), and surface emissivity (ε_o); incoming shortwave radiation ($R_{S\downarrow}$) and the incoming longwave radiation ($R_{L\downarrow}$), the net surface radiation flux (R_n) was computed using Equation (1). Values for R_n can range from 100 – 700 Wm^{-2} depending on the surface.

RESULTS AND DISCUSSIONS

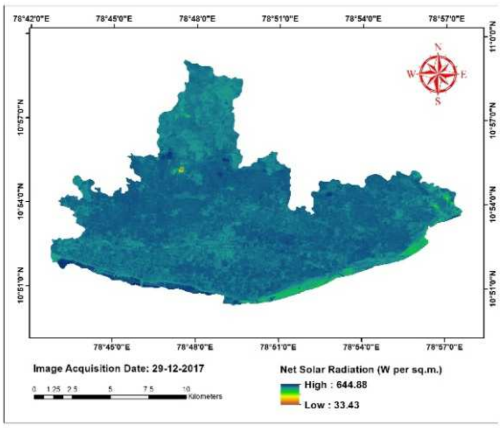
The spatial map of net radiation obtained from the SEBAL model is depicted in Fig. 2 for the selected four scenes of Lalgudi block. The net radiation varied from 380 to 650 W m^{-2}. The maximum net radiation was observed in water bodies that was around 650 W m^{-2}. Like wise Lisboa et al. (2016) also reported maximum values of net radiation for water bodies that varied from 600 to 700 W m^{-2}. Silva et al. (2005) also found R_n of 751.3 Wm^{-2} in SobradinhoLake. The net radiation from water body reduced in Dec 2017 and Jan 2018 scenes because of the presence of water hyacinth in the surface of the water.



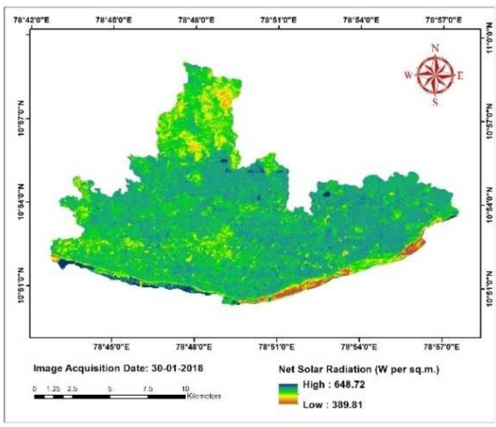
a) December 2014



b) January 2015



c) December 2017



d) January 2018

Figure 2: Spatio-Temporal Variation of Net Radiation (W m^{-2}) in Lalgudi Block

The net radiation from the sand bed of River Colleroon was lesser (450 W m^{-2}) compared to all the other land uses. As well Lisboa et al. (2016) reported minimum values of net radiation for exposed soil which was in the range of 420 to 530 W m^{-2}. Silva et al. (2005) also reported $R_n$values around 420 W m^{-2}in exposed soil.

The net radiation from Paddy, sugarcane, Banana, Forest area, Coconut, and Prosopis was in the range of 560 to 600W m^{-2}. SimilarlyLisboa et al. (2016) also reported net radiation obtained for agriculture was around 560 W m^{-2}in the study conducted at Rio de Janeiro.

Table 2: Net Radiation (W m^{-2}) for Different Land use/Cover in Lalgudi Block

S. No.	Latitude	Longitude	Landuse	Dec 2014	Jan 2015	Dec 2017	Jan 2018
1	10.894	78.923	Lake	641.21	657.51	537.06	535.78
2	10.902	78.784	Coconut	588.21	593.76	581.40	583.28
3	10.931	78.810	Prosopis	568.92	585.52	575.82	580.48
4	10.953	78.817	Barrenland	551.02	562.66	546.67	538.64
5	10.846	78.853	River Sand Bed	456.25	444.90	454.87	447.49
6	10.872	78.816	Lalgudi Town	544.41	565.14	555.10	551.01
7	10.900	78.776	Sugarcane	592.03	571.57	572.22	571.69
8	10.873	78.842	Banana	561.21	577.93	594.53	586.41
9	10.897	78.785	Paddy	579.11	570.98	586.91	561.72
10	10.973	78.797	Forest	576.22	594.39	579.49	585.75

The net radiation from barren land was in the range of 530 to 560 W m^{-2}. This was lesser compared to the cultivated areas and higher compared to the River Sandbed. While closely examining the results, buildup areas inLalgudi town also exhibited similar net radiation as Barren land. Likewise, Lisboa et al. (2016) also reported net radiation for the urban area was around 530 W m^{-2}.

CONCLUSIONS

In this study, the SEBAL algorithm was employed to obtain the net radiation component of different land use/cover using four Landsat 8 images. The calculation gave quantitatively and spatially differentiated net radiation values for different types of land cover in different periods. These results present SEBAL as a vital tool to be used in hydrological and environmental studies. It helps to obtain clear temporal and spatial variations of surface characteristics, helping to improve and validate the model parameters.

ACKNOWLEDGEMENT

This research work was carried out under the assistance provided by Council of Scientific and Industrial Research, New Delhi, India.

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